

Hypersonic Propulsion System Simulation Development



Hypersonic Combined Cycle Engine (CCE) Mode Transition Fundamental Aeronautics – Hypersonic Project

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HiTECC Simulation

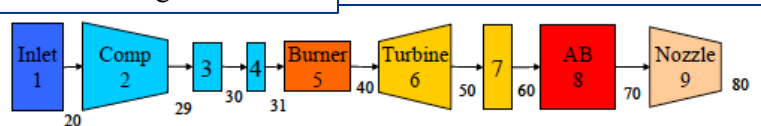
- **H**igh Mach **T**ransient **E**ngine **C**ycle **C**ode (HiTECC)
- Simulation package initially developed by SPIRITECH Advanced Products, Inc.
- Developed under the Hypersonic Project, Guidance Navigation and Control (GN&C) task.
 - Develop tools and procedures for experimental data analysis, control design and evaluation
 - HiTECC used to design and evaluate candidate mode transition/shock position control algorithms



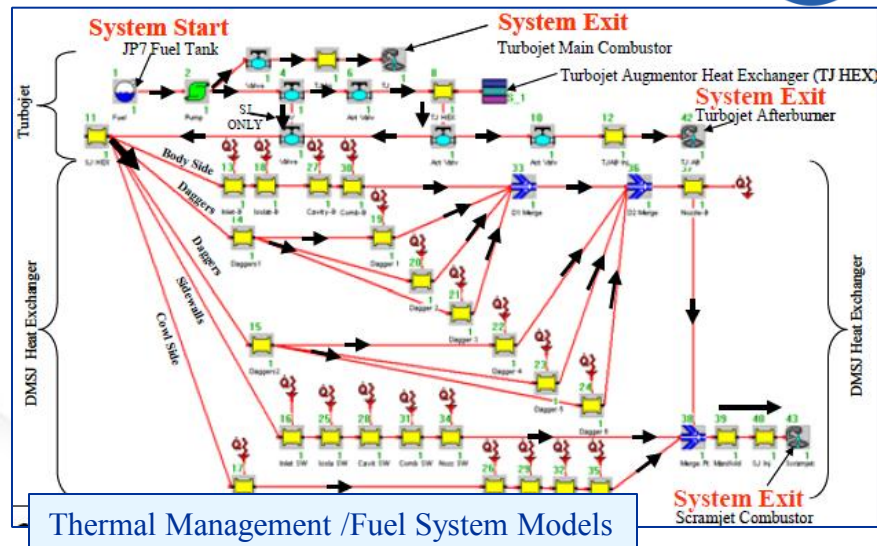
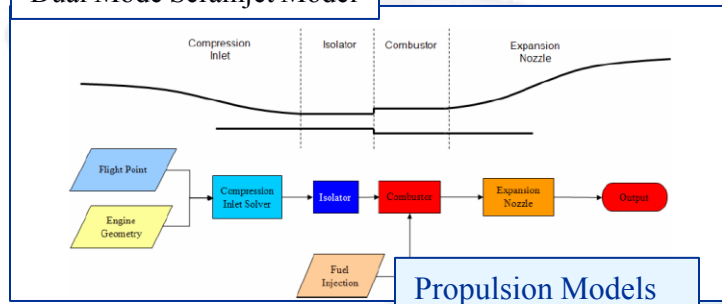
HiTECC Objectives

- Demonstrate all modes of operation of a turbine based combined cycle (TBCC) propulsion system
 - Afterburner, turbine engine, dual mode scram jet
 - Simulate the mode transition sequence of events
- Designed to be generic and modular
 - Inlet geometry is described using the MathWorks® SimScape™
 - Can be used to convert CAD Drawing to Simulink® model file
 - Fast prototyping of inlet designs

Turbo Jet Engine Model

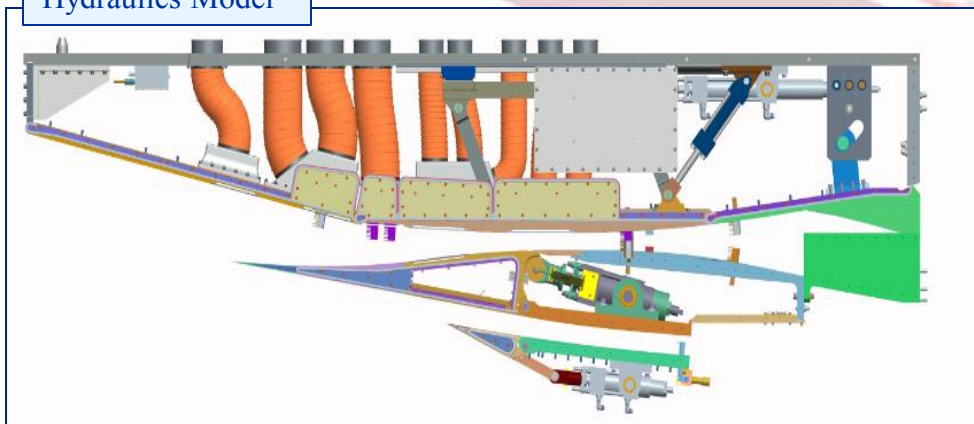


Dual Mode Scramjet Model

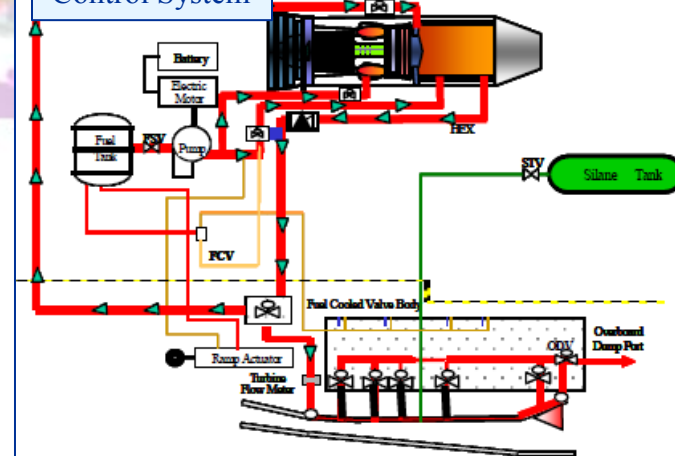


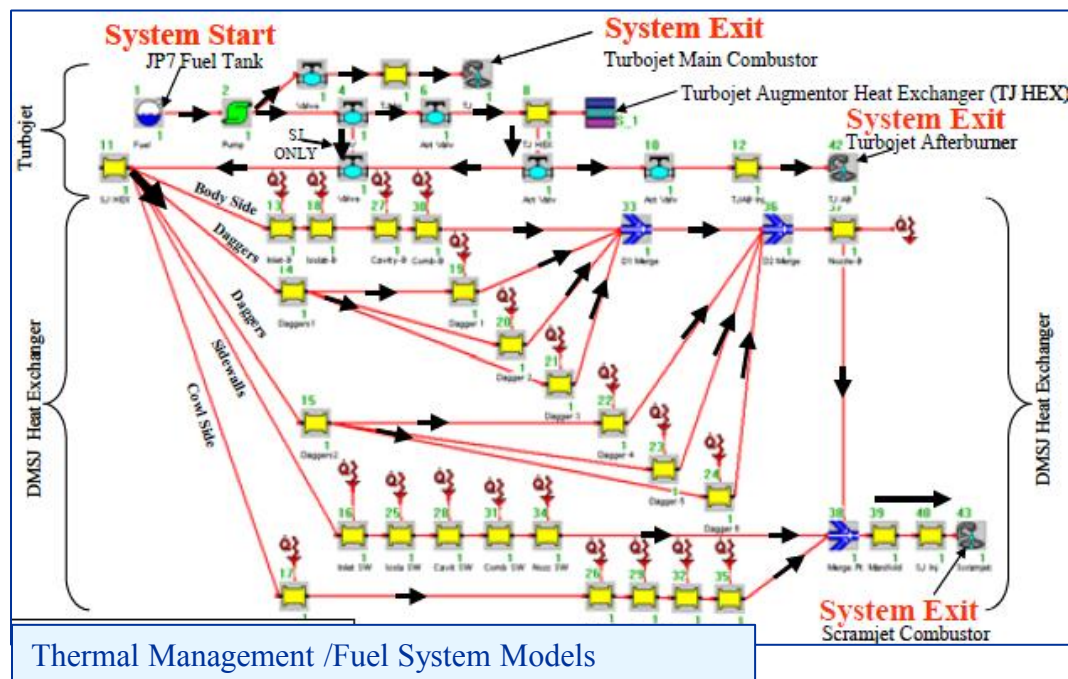
High Mach Transient Engine Cycle Code (HiTECC)

Hydraulics Model



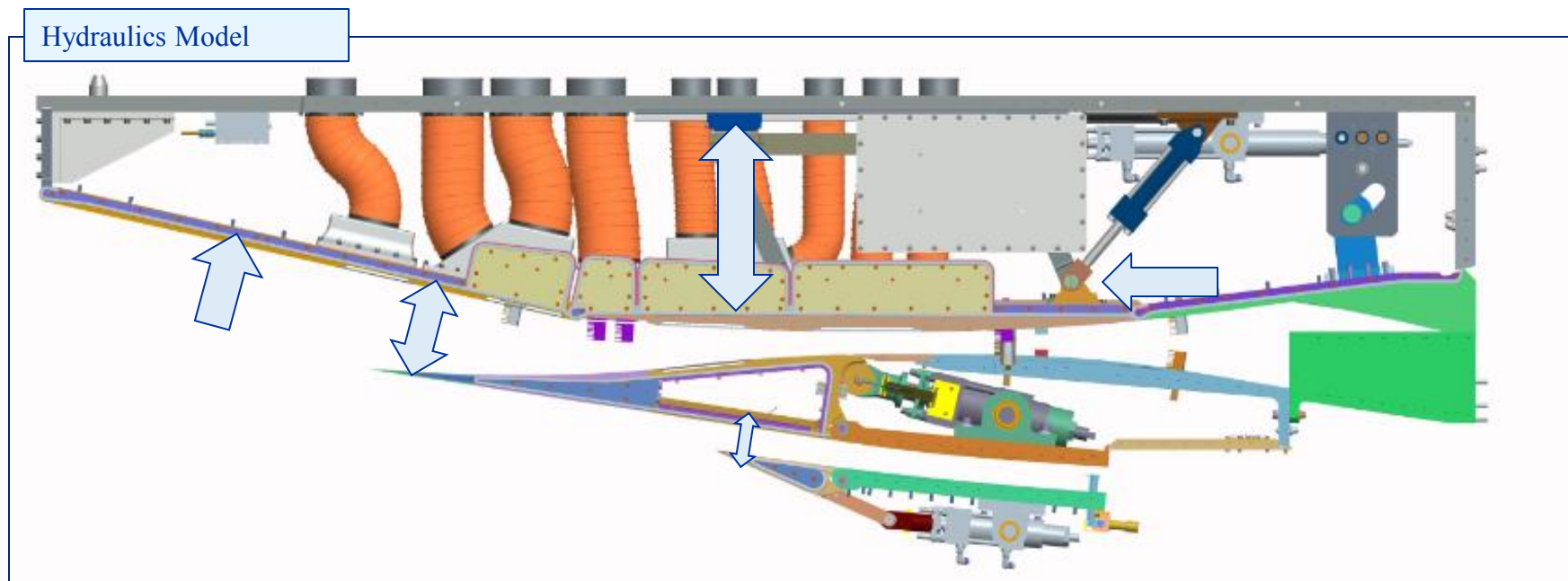
Control System



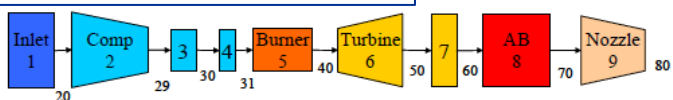


- Simulates fuel flow, fluid energy, and thermal energy transfer for both the LSFP and HSFP
- Couples a transient flow model and a transient thermal model
- One-dimensional compressible flow solver allows a variety of fuels, including hydrogen, to be modeled

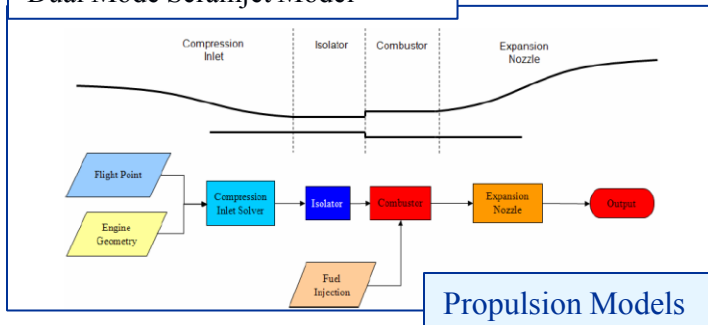
- Simulates the kinematic features of the variable inlet and nozzle for both flow paths
- Models the dynamic response of the hydraulic fluid
- Models for the power storage and generation for pumping the hydraulic fluid



Turbo Jet Engine Model



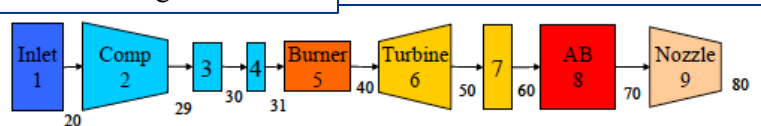
Dual Mode Scramjet Model



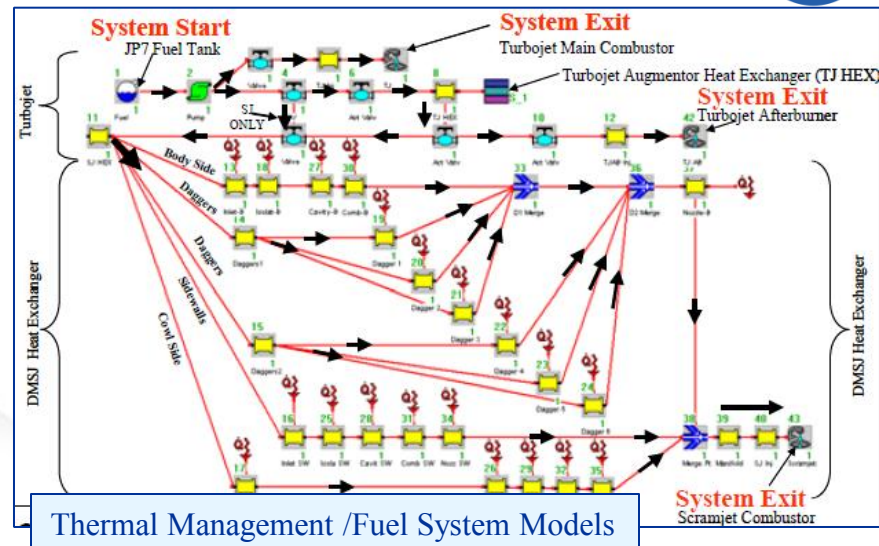
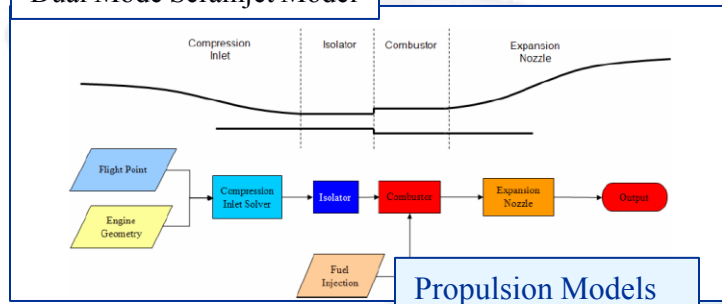
Assume Started
Low-Speed and
High-Speed Inlets
(No external
normal shocks)

- Variable Inlet Model (P,T,W)
 - External Compression
 - Inviscid thermally perfect oblique shock theory
 - Supersonic Internal
 - Thermally perfect 1-dimensional steady-state compressible flow
 - Subsonic Internal
 - Unsteady subsonic compression model (control volume)
- Gas Turbine Model
 - Simple 0-dimensional engine model
- Dual Mode Scramjet
 - Isolator
 - Quasi 1-dimensional compressible flow equations
 - Combustor
 - Quasi 1-dimensional combustor model
- Nozzles
 - A simplified, 1-dimensional nozzle model

Turbo Jet Engine Model

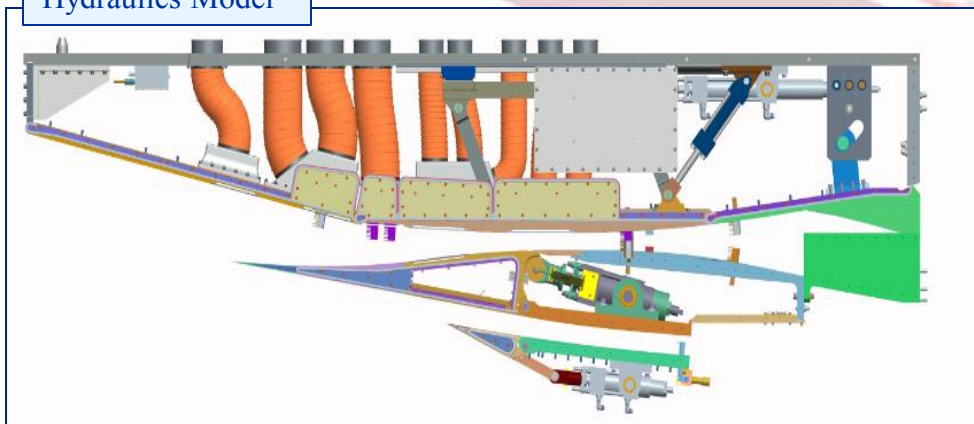


Dual Mode Scramjet Model

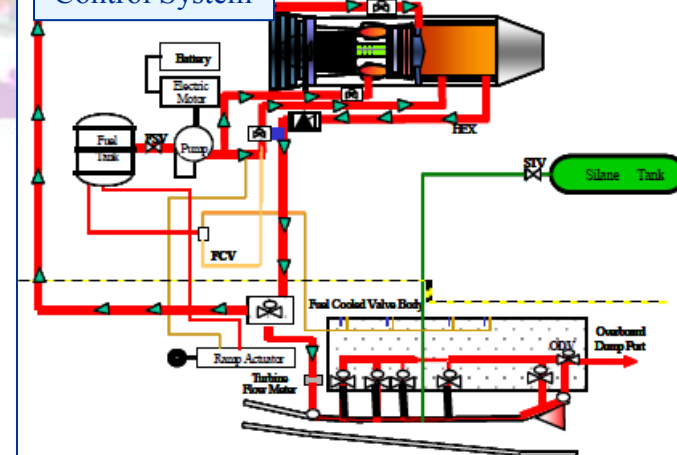


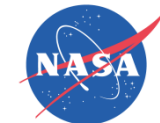
High Mach Transient Engine Cycle Code (HiTECC)

Hydraulics Model



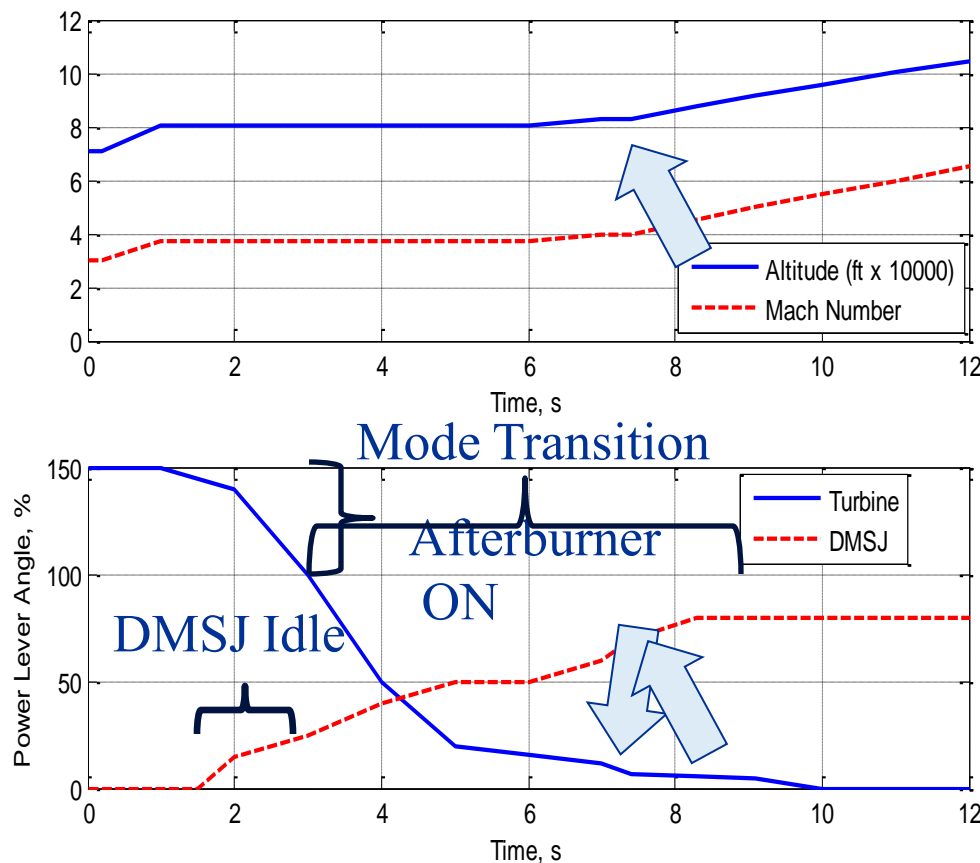
Control System



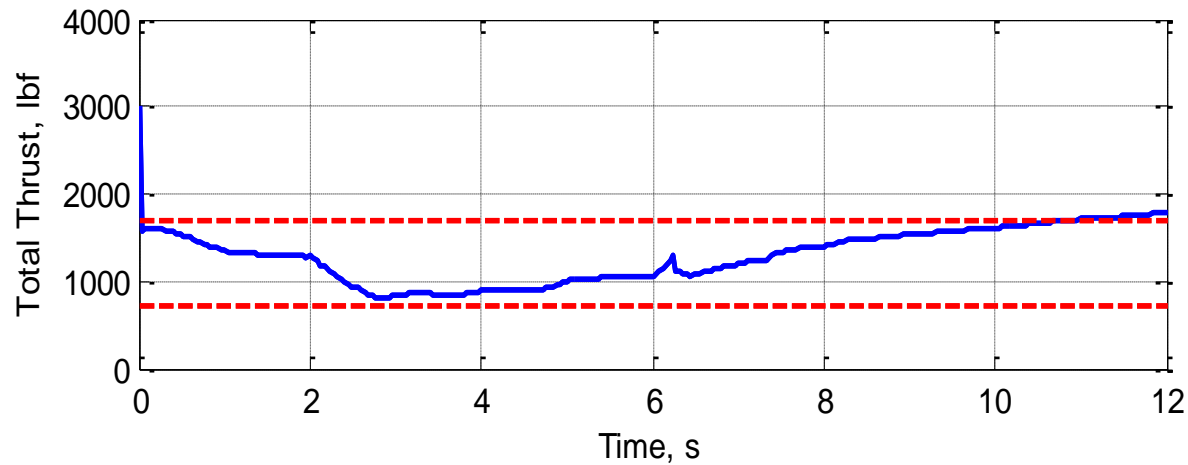
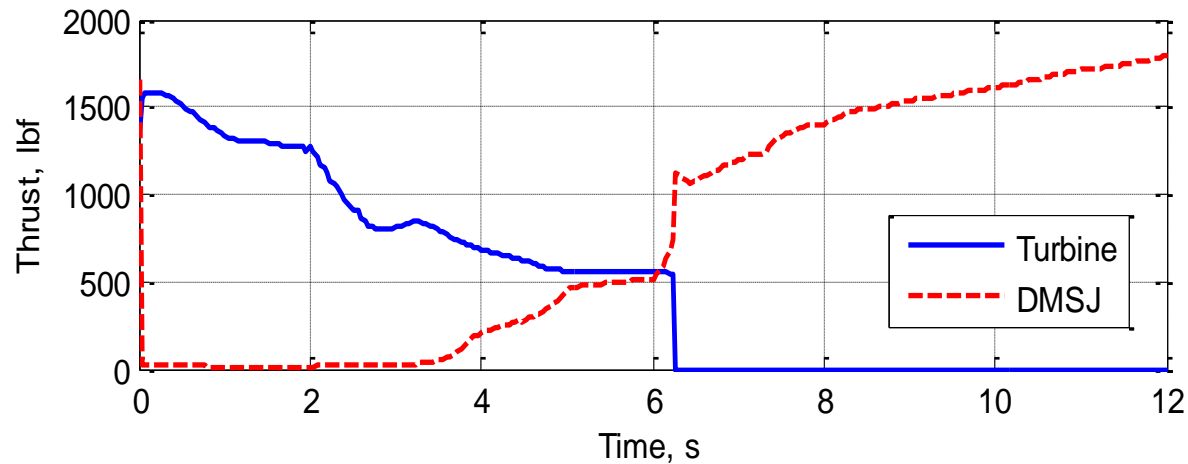


Mode Transition with HiTECC

- Mode transition occurs Mach 3.0 -4.0
- Mode transition sequence of events
 - Reach mode transition flight condition (M3.75)
 - Begin afterburner shutdown
 - Start DMSJ
 - Transition power
 - Close off LSFP/ shutdown turbine engine
 - Continue with mission

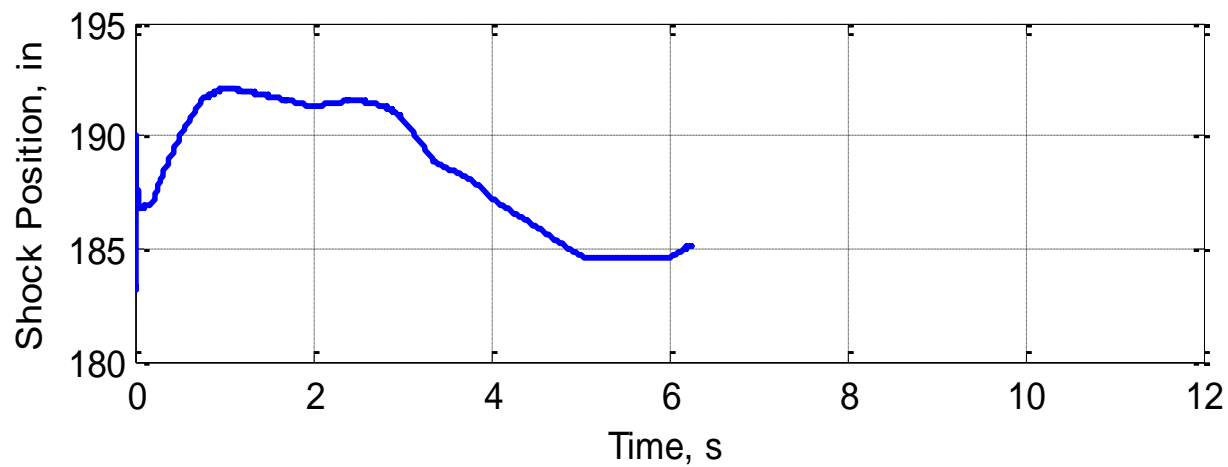
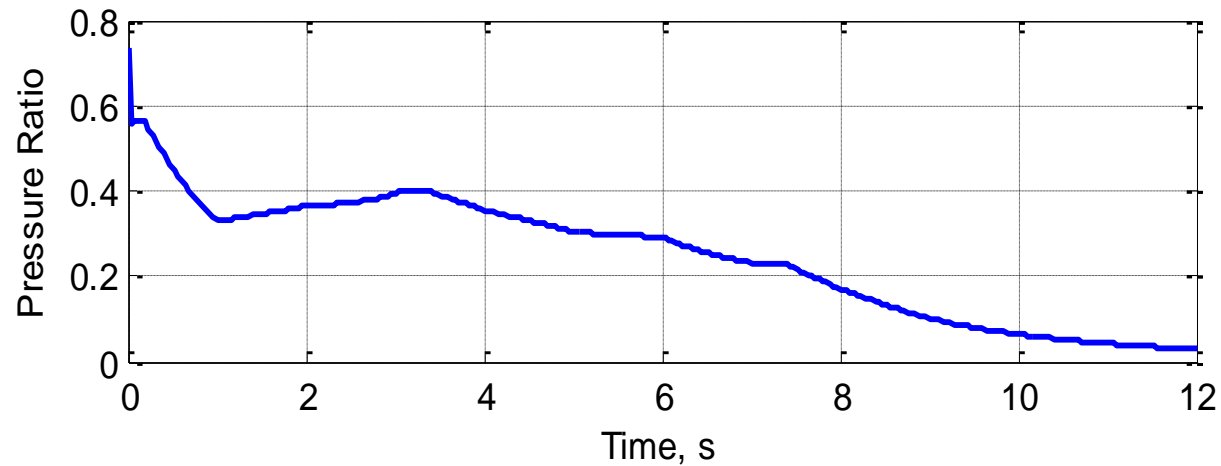


Mode Transition with HiTECC

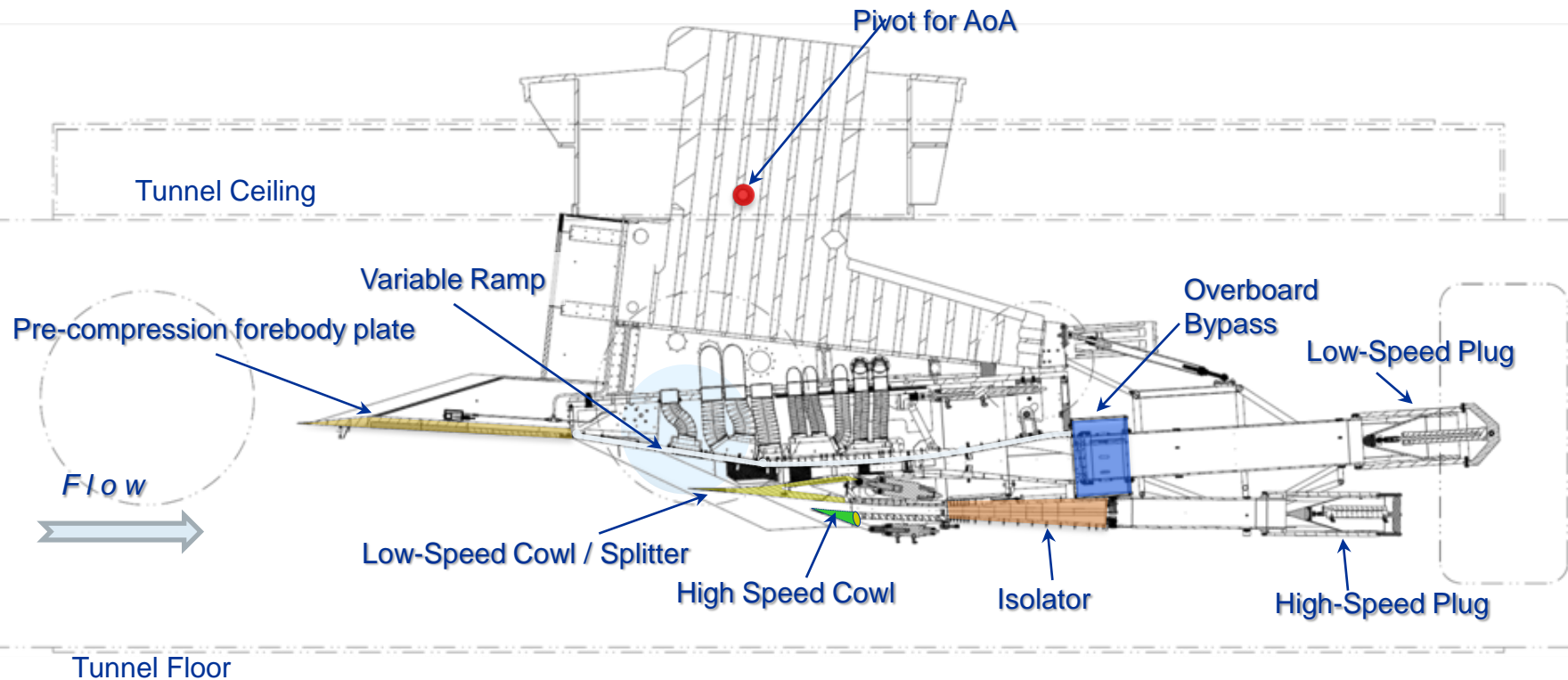




Mode Transition with HiTECC

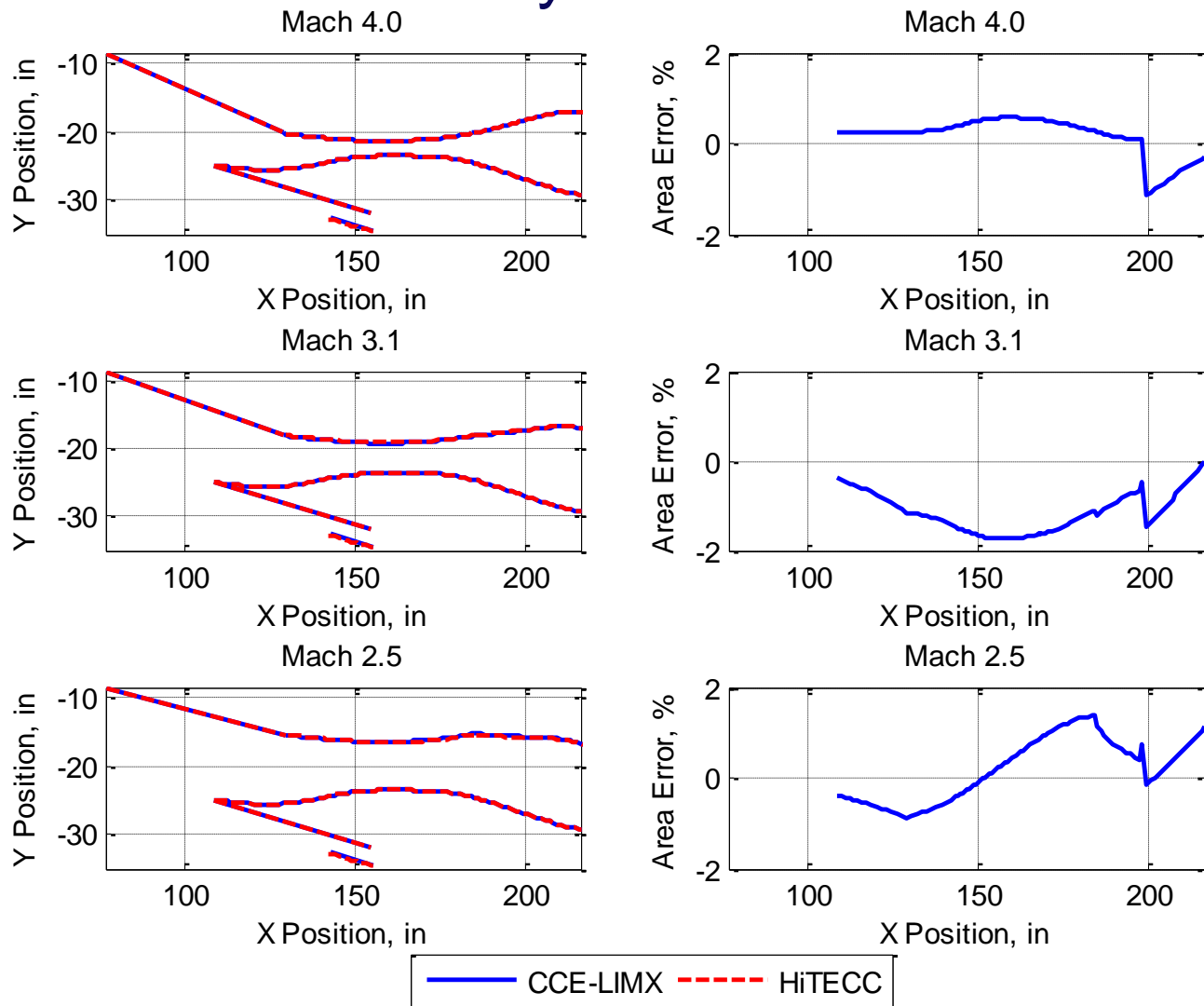


Large-scale Inlet model for Combined Cycle Engine Mode Transition Studies (CCE-LIMX)

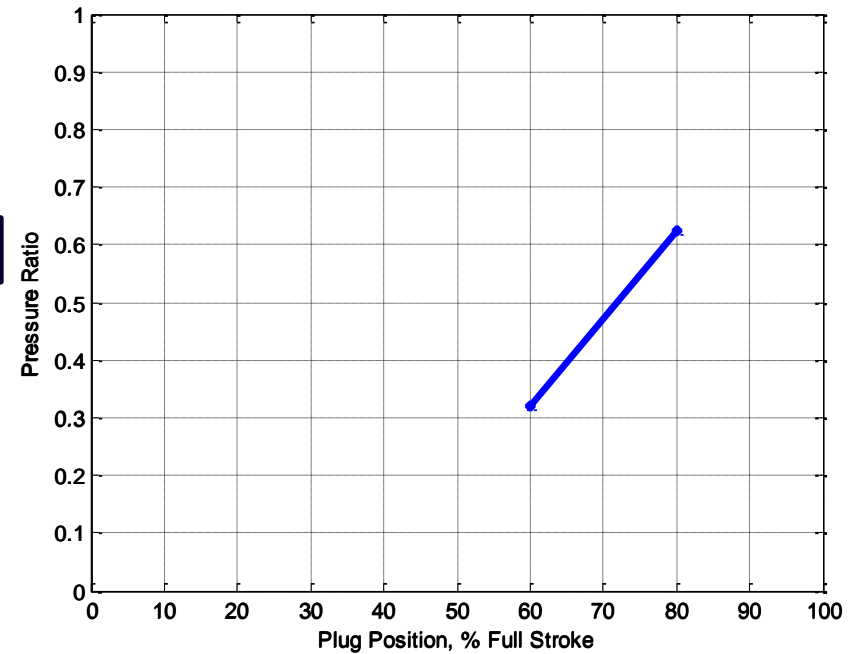
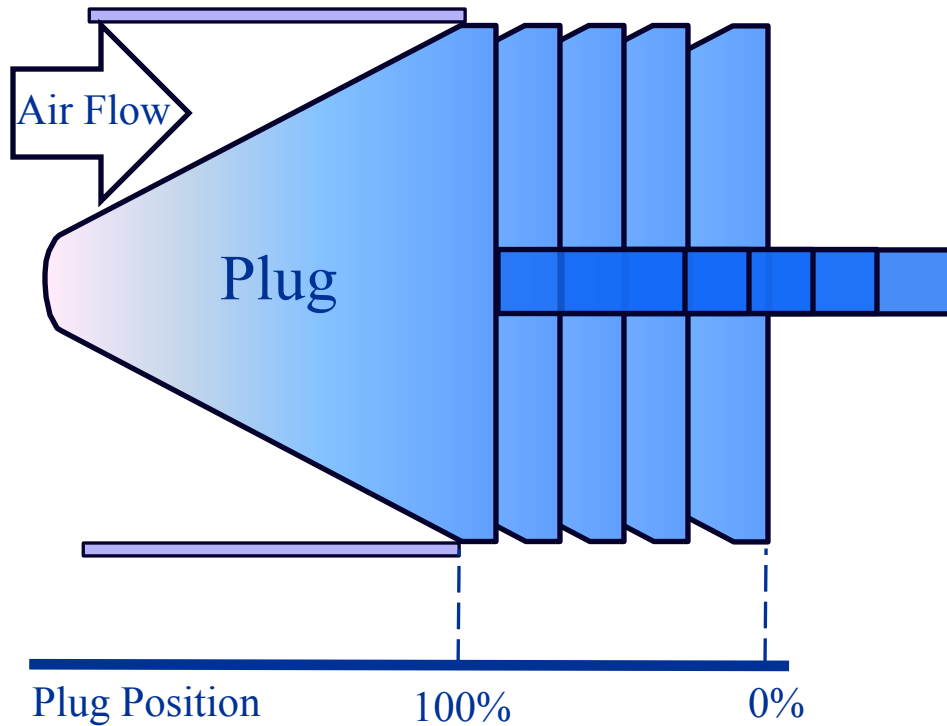




Redesign Geometry, Actuators, and Control Systems

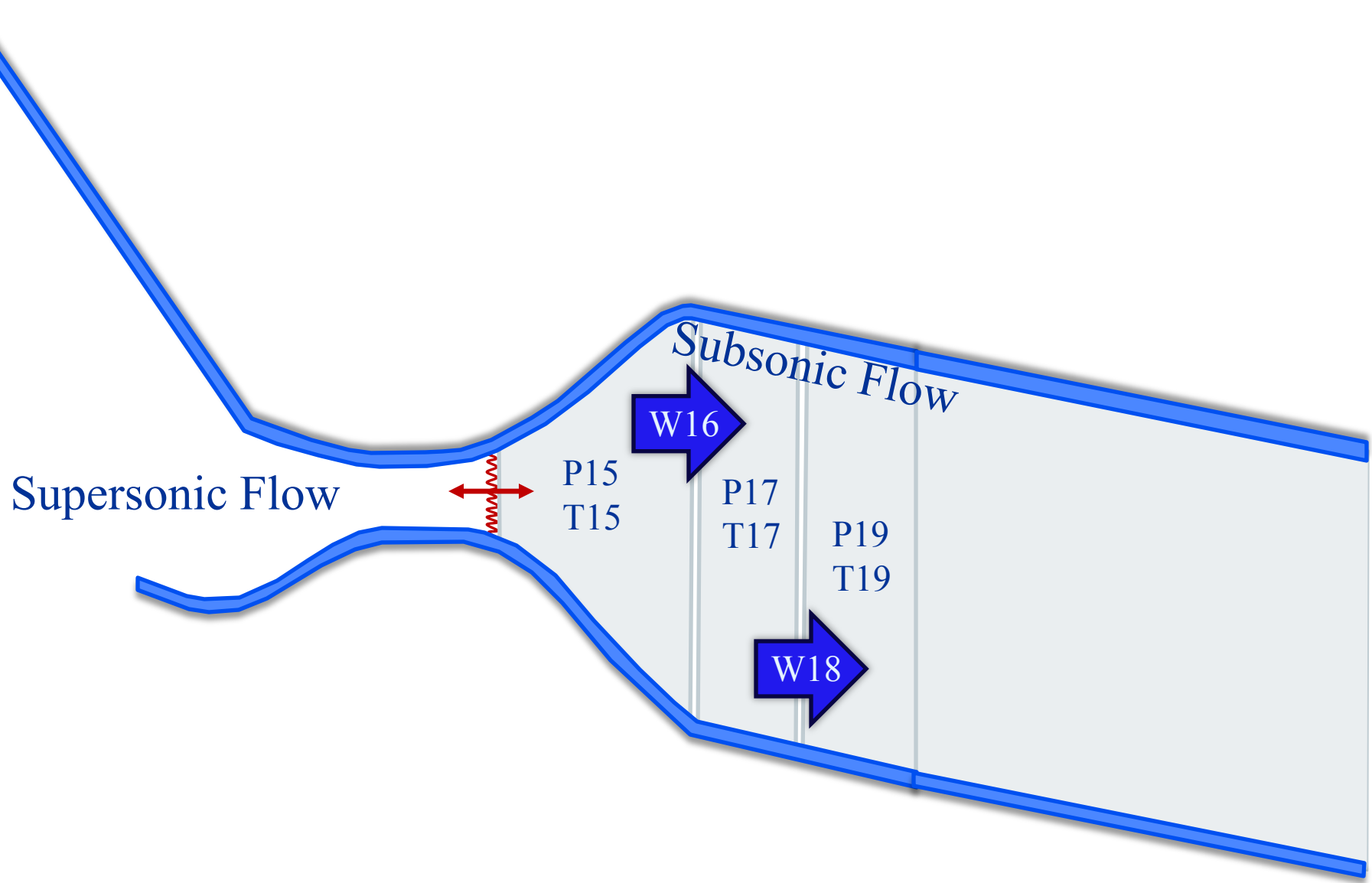


Replacement of Turbine Engines with a Plug



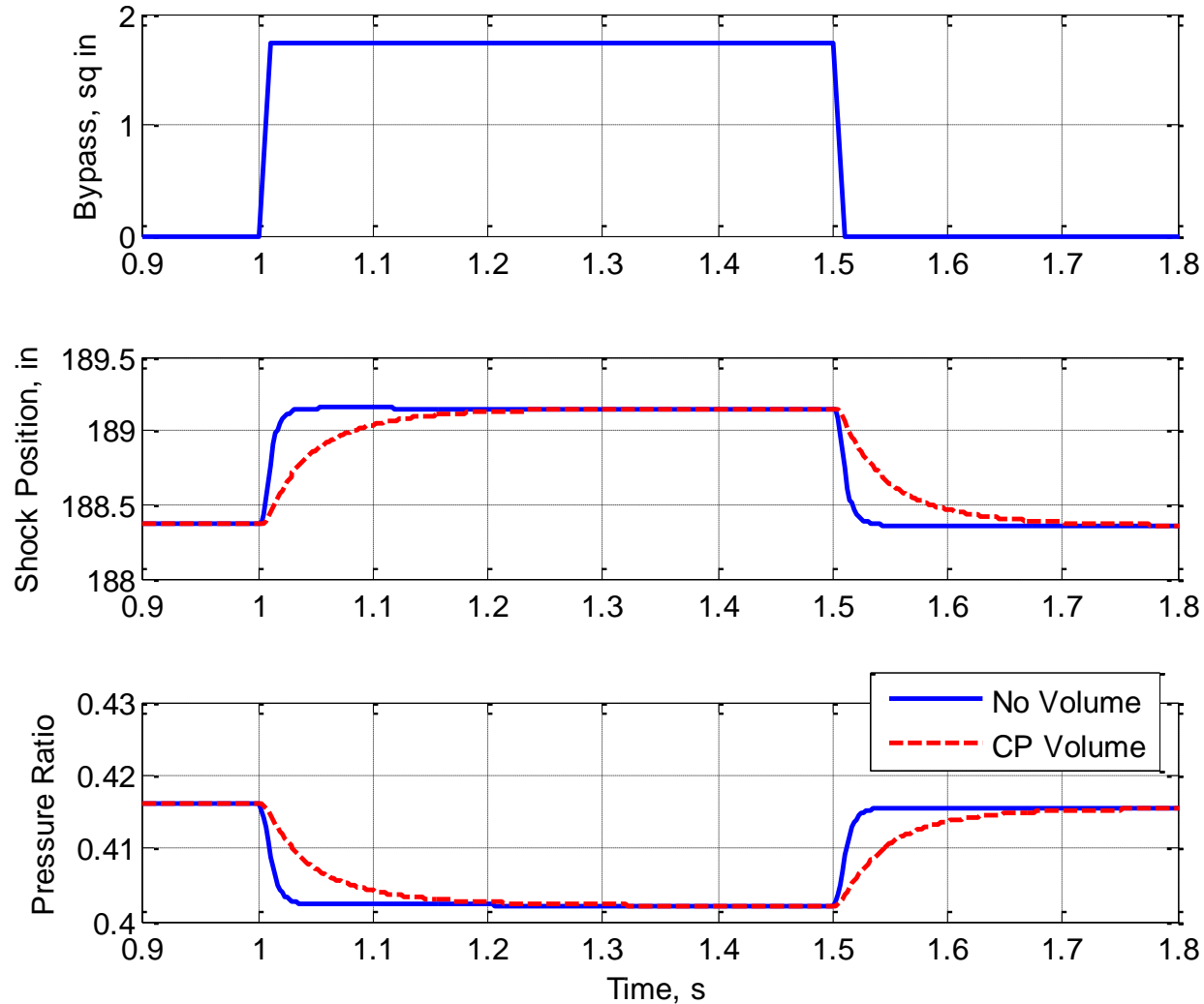


Addition of the Cold Pipe Volume





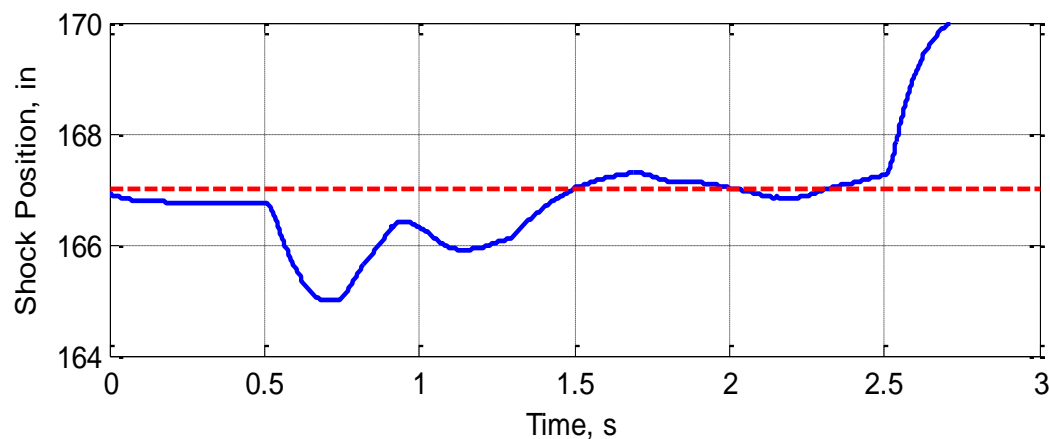
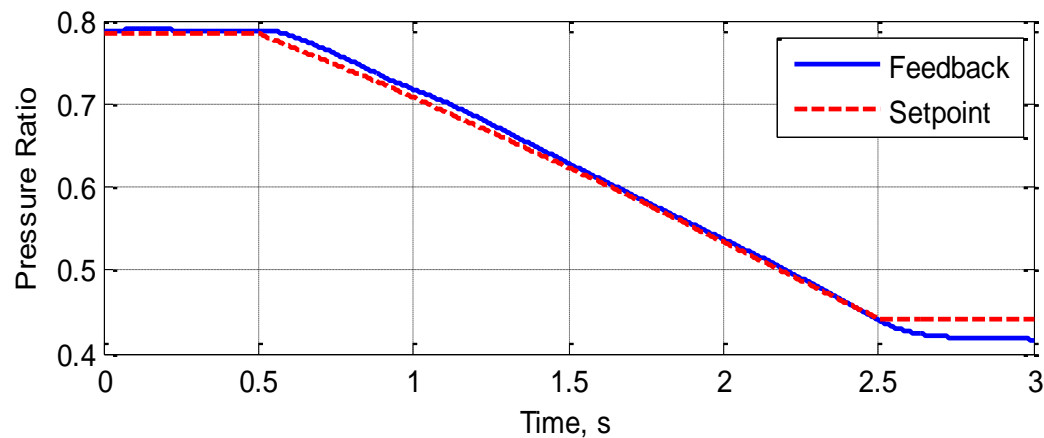
Dynamic Response with Additional Volume





Mode Transition with the CCE-LIMX

- Pressure ratio setpoint is dependent on the splitter angle
- System is driven to starting pressure ratio by the plug





Future Work with HiTECC

- Develop linear models for diffuser (subsonic).
- Compare experimental data with HiTECC.
- Use HiTECC to develop and test candidate mode transition control algorithms before implementation.